LIFE TABLE AND DEMOGRAPHIC PARAMETERS OF PAPAYA MEALYBUG, *PARACOCCUS MARGINATUS* (HEMIPTERA: PSEUDOCOCCIDAE) ON *HIBISCUS ROSA-CHINENSIS*

[1, 2]M. I. Mastoi, [1]A. Nur Azura, [1]R. Muhamad, [3]A. B. Idris, [4]A. G. Arfan and [5]Y. Ibrahim
[1]Department of Plant Protection, Faculty of Agriculture, Universiti Putra Malaysia.
[2]National IPM Programme, Department of Plant and Environmental Protection, NARC, Islamabad, Pakistan.
[3]School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia
[4]Department of Entomology, Faculty of Crop Protection, Sindh Agriculture University Tandojam
[5]Department of Agricultural Science, Faculty of Technical and Vocational Education, Universiti Pendidikan Sultan Idris, Perak, Malaysia.
Corresponding author: Muhammad Ishaque Mastoi Email: ishaqnscri@yahoo.com

ABSTRACT: *The papaya mealybug Paracoccus marginatus is an imperative insect pest because of its invasive and polyphagous nature. Age-specific life and fertility tables of P. marginatus were constructed in laboratory conditions (27±2 ^{o}C, 60±5% RH). Survival and fertility characteristics of P. marginatus were observed on basis of provision of unlimited food source (Fresh hibiscus leaves) with pesticide and natural enemy free environment. The highest apparent mortality (20.1%) was observed in the 1st instar nymphs with k-value of .097 indicating the key factor in regulating pest population size. The proportion of female to male was 1.09:1. The values for net reproductive rate (R_o), mean generation time (T_c), intrinsic rate of increase (r_c), innate capacity of increase (r_m), finite rate of increase (λ), and doubling time were recorded as 43.36 female offsprings per female, 30.73 days, 0.1248 / day, 0.1227 / day, 1.1329 female offsprings / female and 5.65 days respectively. These results will play vital role in development of reliable and sustainable IPM strategy for the pest.*

Keywords: Life table, demography, papaya, mealybug

INTRODUCTION

Life table is a concise summary of certain vital statistics of a population [1]. According to Rockwood, the life tables summarize the fate of a cohort (group of individuals) born at the same time and follow the survivorship of these individuals until the last member of the cohort dies. It uses information on age-specific mortality rates to determine the patterns of survivorship and life expectancy [2]. Construction of life tables begins through collection of information on survivorship by age class. Ecological life tables are among the key research tools used in the qualitative and quantitative assessment of factors involved in the natural mortality of herbivore insects [3, 4]. Construction of life tables is a key element to understand the population dynamics of species [5]. Life tables illustrate the detailed account of the age-specific survival rate and fecundity of insect populations. This information can also be utilized to project the population growth and stage differentiation. Potential population growth of an insect on variety of host plants in various environmental conditions can be determined by using life tables. It can also be used in same conditions to compare different insects. Plant damage estimation by insect pest population can be assessed, if we combine the life table study with consumption rate study. It is also possible to estimate the potential of a predator as potential biological control agent, if we combine the life table study with the study of predation rate of a predatory insect. Life tables are the most important basis for qualitative and quantitative study of population ecology. The critical mortality stage and key mortality factors have been determined in numerous studies on different insect pests [6, 7, 8, 9]. There are two types of life tables commonly used by ecologists, the age-specific life table and time-specific life table. Age-specific life tables are based on the fates of individuals in a real cohort (a group of individuals born in the same time interval), whereas a time-specific life tables are based on the fate of individuals in an imaginary cohort derived from the age structure of a stable population with overlapping generations at a point in time [5]. Because, most of the insects have discrete generations and unstable populations, the age-specific life table is more applicable than the time-specific life table. Life table and demographic parameters of pests are most important key factors to understand the population dynamics [5] and it plays major role in integrated pest management strategy. Papaya mealybug, *Paracoccus marginatus* is an invasive pest reported infesting papaya plants in many South-East Asian countries including Malaysia [10, 11]. Thus, to understand the population dynamics of papaya mealybug, a detailed study on life table and demographic parameters of *P. marginatus* was conducted on hibiscus (*Hibiscus rosa-sinensis*) under laboratory conditions.

MATERIAL AND METHODS

Rearing of *P. marginatus*: *Paracoccus marginatus* culture was maintained on unripe green papaya fruits in the entomology laboratory, Universiti Putra Malaysia at an ambient temperature of 26 ± 2°C and 60 ± 5% relative humidity with 12:12 (LD) photoperiod. Plastic containers (10 litre capacity) were used as rearing chambers. Two to three medium sized unripe papaya fruits were placed in each rearing chamber and 10-12 adult gravid females per papaya fruit (with or without ovisacs) were introduced for multiplication of culture.

Construction of life table: Newly emerged adults at the ratio of 2:1 (male: female) were obtained from laboratory culture and transferred on hibiscus leaves in petri dishes for mating and oviposition. One day old eggs were collected for constructing of life tables. The study was conducted on four cohorts (1, 2, 3 and 4); each consisting of 120, 137, 102 and 100 eggs obtained on 10 February, 15 February, 10 April and 10 April 2010 respectively. The experimental arena for life table study consisted of a 9 cm diameter plastic petri dishes. About 0.5 cm diameter hole was made in the bottom of the petri dish using a heated cork borer for petiole of hibiscus leaf and the cover of petri dish was cut in the centre in square shape about 5 cm diameter to attach muslin cloth with glue to allow the air circulation inside the Petri dish. A tender hibiscus leaf with a 3-4 cm long petiole was placed in each Petri dish with the petiole inserted through the hole at the bottom of the Petri dish. Each Petri dish with a hibiscus leaf was placed on a cup of water so that the petiole to be immersed for maintaining leaf freshness. Ten eggs per one petri dish were introduced and the petri dish was sealed around by using parafilm to avoid the escape of mealybug nymphs. Survival and fecundity of each individual was recorded till death of the last individual.

Data analysis: The data were analyzed following the single sex method. Life and fecundity tables were constructed from daily account of mortality and fecundity of four cohorts following the procedures of Birch [12] and Southwood [5]. The parameters calculated were as follows:

x: age class in units of time (days) / developmental stage

l_x: number surviving individuals at beginning of age class(x)
The number of individuals alive, during a given age interval class as a fraction of an initial population of one

L_x: number of individuals alive between age x and x+1, $L_x = (l_x + l_{x+1})$ ½

d_x: number dying during age interval x

100_{qx}: Percent apparent mortality, $100q_x = (d_x/l_x)100$

S_x: survival stage rate within stage

T_x: total number of age x units beyond the age x

e_x: life expectancy for individuals of age x, $e_x = T_x/l_x$

m_x: age-specific fertility, the number of living females born per female in each age interval

R_o: net reproductive rate, multiplication rate per generation, $R_o=\sum l_x m_x$

R_c: innate capacity for increase, $R_c = \ln R_o / T_c$

R_m: intrinsic rate of natural increase or maximum population growth, calculated by iteration of Euler's equation, $\sum e^{-rm.x} l_x m_x = 1$

T_c: cohort generation time (in day), $T_c = \sum x l_x m_x / \sum l_x m_x$

T: corrected generation time, $T = \ln R_o / r_m$

λ: Finite rate of increase, the number of female off-springs female^{-1} day^{-1}, $\lambda = e^{rm}$

DT: doubling time, the number of days required by a population to double, $DT= \ln 2 / r_m$

b: intrinsic birth rate, $b = 1 / \sum e^{-rm.x} l_x$

d: intrinsic death rate, $d = b - r_m$

RESULTS AND DISCUSSIONS

Age specific survival life table:

The patterns of survivorship curves of four cohorts of *P. marginatus* reared on hibiscus are shown in figure 1 and comprehensive data of each cohort is given in tables 1, 2, 3 and 4. In cohort 1, 93% egg hatchability of *P. marginatus* was recorded and total 63.62% individuals survived till adults. The higher nymphal mortalities were recorded on day 8 (11.71%) in 1st instar nymphs and on day 13 (4.62%) in second instar nymphs, while reduced mortality was found in subsequent nymphal stages. The female papaya mealybug underwent three moults and male four moults to become adults. The first adult female emerged on day 20 and the last female died on day 47 (Table 1).

Table 1: Age-Specific Life Table of *P. marginatus* (Cohort 1)

x	l_x	d_x	L_x	100_{qx}	S_x	T_x	e_x
1	1.00	0	120.00	0.00	100.00	2762.00	23.02
2	1.00	0	120.00	0.00	100.00	2642.00	22.02
3	1.00	0	120.00	0.00	100.00	2522.00	21.02
4	1.00	0	120.00	0.00	100.00	2402.00	20.02
5	1.00	0	120.00	0.00	100.00	2282.00	19.02
6	1.00	0	120.00	0.00	100.00	2162.00	18.02
7	1.00	9	115.50	7.50	92.50	2042.00	17.02
8	0.93	13	104.50	11.71	88.29	1926.50	17.36
9	0.82	4	96.00	4.08	95.92	1822.00	18.59
10	0.78	3	92.50	3.19	96.81	1726.00	18.36
11	0.76	2	90.00	2.20	97.80	1633.50	17.95
12	0.74	2	88.00	2.25	97.75	1543.50	17.34
13	0.73	4	85.00	4.60	95.40	1455.50	16.73
14	0.69	2	82.00	2.41	97.59	1370.50	16.51
15	0.68	1	80.50	1.23	98.77	1288.50	15.91
16	0.67	3	78.50	3.75	96.25	1208.00	15.10
17	0.64	1	76.50	1.30	98.70	1129.50	14.67
18	0.63	0	76.00	0.00	100.00	1053.00	13.86
19	0.63	0	76.00	0.00	100.00	977.00	12.86
20	0.63	1	75.50	1.32	98.68	901.00	11.86
21	0.63	7	71.50	9.33	90.67	825.50	11.01
22	0.57	8	64.00	11.76	88.24	754.00	11.09
23	0.50	7	56.50	11.67	88.33	690.00	11.50
24	0.44	5	50.50	9.43	90.57	633.50	11.95
25	0.40	6	45.00	12.50	87.50	583.00	12.15
26	0.35	2	41.00	4.76	95.24	538.00	12.81
27	0.33	0	40.00	0.00	100.00	497.00	12.43
28	0.33	1	39.50	2.50	97.50	457.00	11.43
29	0.33	0	39.00	0.00	100.00	417.50	10.71
30	0.33	0	39.00	0.00	100.00	378.50	9.71
31	0.33	0	39.00	0.00	100.00	339.50	8.71
32	0.33	0	39.00	0.00	100.00	300.50	7.71
33	0.33	1	38.50	2.56	97.44	261.50	6.71
34	0.32	3	36.50	7.89	92.11	223.00	5.87
35	0.29	2	34.00	5.71	94.29	186.50	5.33
36	0.28	2	32.00	6.06	93.94	152.50	4.62
37	0.26	6	28.00	19.35	80.65	120.50	3.89
38	0.21	0	25.00	0.00	100.00	92.50	3.70
39	0.21	5	22.50	20.00	80.00	67.50	2.70
40	0.17	7	16.50	35.00	65.00	45.00	2.25
41	0.11	5	10.50	38.46	61.54	28.50	2.19
42	0.07	3	6.50	37.50	62.50	18.00	2.25
43	0.04	2	4.00	40.00	60.00	11.50	2.30
44	0.03	0	3.00	0.00	100.00	7.50	2.50
45	0.03	1	2.50	33.33	66.67	4.50	1.50
46	0.02	1	1.50	50.00	50.00	2.00	1.00
47	0.01	1	0.50	100.00	0.00	0.50	0.50

x=developmental stage in days, l_x=proportion of number entering stage, d_x=number dying in stage x, L_x=number alive between age x and x+1, 100_{qx}=percent apparent mortality, S_x=survival rate within stage, T_x=Total number of age x units beyond the age, e_x=life expectancy

All cohorts exihibited almost same survivorship pattern by recording 94-96% egg hatchabilty and 61-66% individual survivorship of adults. The higher mortalities occured in 1st instar nymphs on days 9, 10 and 11, while in second instar nymphs higher mortality was recorded on day 13 and 14 respectively. The first adult female emerged on day 19 in cohort 2 and 3, and on day 20 in cohort 4. The last female died on day 47 in cohort 2 and on day 46 in cohort 3 and 4 (Tables 2, 3 and 4).

Table 2: Age-Specific Life Table of *P. marginatus* (Cohort 2)

X	l_x	d_x	L_x	100_{qx}	S_x	T_x	e_x
1	1.00	0	137.00	0.00	100.00	3237.50	23.63
2	1.00	0	137.00	0.00	100.00	3100.50	22.63
3	1.00	0	137.00	0.00	100.00	2963.50	21.63
4	1.00	0	137.00	0.00	100.00	2826.50	20.63
5	1.00	0	137.00	0.00	100.00	2689.50	19.63
6	1.00	0	137.00	0.00	100.00	2552.50	18.63
7	1.00	0	137.00	0.00	100.00	2415.50	17.63
8	1.00	8	133.00	5.84	94.16	2278.50	16.63
9	0.94	6	126.00	4.65	95.35	2145.50	16.63
10	0.90	8	119.00	6.50	93.50	2019.50	16.42
11	0.84	9	110.50	7.83	92.17	1900.50	16.53
12	0.77	3	104.50	2.83	97.17	1790.00	16.89
13	0.75	8	99.00	7.77	92.23	1685.50	16.36
14	0.69	5	92.50	5.26	94.74	1586.50	16.70
15	0.66	2	89.00	2.22	97.78	1494.00	16.60
16	0.64	1	87.50	1.14	98.86	1405.00	15.97
17	0.64	2	86.00	2.30	97.70	1317.50	15.14
18	0.62	1	84.50	1.18	98.82	1231.50	14.49
19	0.61	0	84.00	0.00	100.00	1147.00	13.65
20	0.61	1	83.50	1.19	98.81	1063.00	12.65
21	0.61	8	79.00	9.64	90.36	979.50	11.80
22	0.55	12	69.00	16.00	84.00	900.50	12.01
23	0.46	6	60.00	9.52	90.48	831.50	13.20
24	0.42	6	54.00	10.53	89.47	771.50	13.54
25	0.37	4	49.00	7.84	92.16	717.50	14.07
26	0.34	0	47.00	0.00	100.00	668.50	14.22
27	0.34	0	47.00	0.00	100.00	621.50	13.22
28	0.34	0	47.00	0.00	100.00	574.50	12.22
29	0.34	0	47.00	0.00	100.00	527.50	11.22
30	0.34	0	47.00	0.00	100.00	480.50	10.22
31	0.34	0	47.00	0.00	100.00	433.50	9.22
32	0.34	0	47.00	0.00	100.00	386.50	8.22
33	0.34	0	47.00	0.00	100.00	339.50	7.22
34	0.34	2	46.00	4.26	95.74	292.50	6.22
35	0.33	6	42.00	13.33	86.67	246.50	5.48
36	0.28	5	36.50	12.82	87.18	204.50	5.24
37	0.25	1	33.50	2.94	97.06	168.00	4.94
38	0.24	2	32.00	6.06	93.94	134.50	4.08
39	0.23	5	28.50	16.13	83.87	102.50	3.31
40	0.19	7	22.50	26.92	73.08	74.00	2.85
41	0.14	4	17.00	21.05	78.95	51.50	2.71
42	0.11	3	13.50	20.00	80.00	34.50	2.30
43	0.09	6	9.00	50.00	50.00	21.00	1.75
44	0.04	2	5.00	33.33	66.67	12.00	2.00
45	0.03	1	3.50	25.00	75.00	7.00	1.75
46	0.02	1	2.50	33.33	66.67	3.50	1.17
47	0.01	2	1.00	100.00	0.00	1.00	0.50

x=developmental stage in days, l_x=proportion of number entering stage, d_x=number dying in stage x, L_x=number alive between age x and x+1, 100_{qx}=percent apparent mortality, S_x=survival rate within stage, T_x=Total number of age x units beyond the age, e_x=life expectancy

Table 3: Age-Specific Life Table of *P. marginatus* (Cohort 3)

X	l_x	d_x	L_x	100_{qx}	S_x	T_x	e_x
1	1.00	0	102.00	0.00	100.00	2366.00	23.20
2	1.00	0	102.00	0.00	100.00	2264.00	22.20
3	1.00	0	102.00	0.00	100.00	2162.00	21.20
4	1.00	0	102.00	0.00	100.00	2060.00	20.20
5	1.00	0	102.00	0.00	100.00	1958.00	19.20
6	1.00	0	102.00	0.00	100.00	1856.00	18.20
7	1.00	0	102.00	0.00	100.00	1754.00	17.20
8	1.00	5	99.50	4.90	95.10	1652.00	16.20
9	0.95	6	94.00	6.19	93.81	1552.50	16.01
10	0.89	8	87.00	8.79	91.21	1458.50	16.03
11	0.81	4	81.00	4.82	95.18	1371.50	16.52
12	0.77	3	77.50	3.80	96.20	1290.50	16.34
13	0.75	3	74.50	3.95	96.05	1213.00	15.96
14	0.72	3	71.50	4.11	95.89	1138.50	15.60
15	0.69	2	69.00	2.86	97.14	1067.00	15.24
16	0.67	1	67.50	1.47	98.53	998.00	14.68
17	0.66	1	66.50	1.49	98.51	930.50	13.89
18	0.65	0	66.00	0.00	100.00	864.00	13.09
19	0.65	0	66.00	0.00	100.00	798.00	12.09
20	0.65	3	64.50	4.55	95.45	732.00	11.09
21	0.62	3	61.50	4.76	95.24	667.50	10.60
22	0.59	10	55.00	16.67	83.33	606.00	10.10
23	0.49	12	44.00	24.00	76.00	551.00	11.02
24	0.37	8	34.00	21.05	78.95	507.00	13.34
25	0.29	0	30.00	0.00	100.00	473.00	15.77
26	0.29	0	30.00	0.00	100.00	443.00	14.77
27	0.29	0	30.00	0.00	100.00	413.00	13.77
28	0.29	0	30.00	0.00	100.00	383.00	12.77
29	0.29	0	30.00	0.00	100.00	353.00	11.77
30	0.29	0	30.00	0.00	100.00	323.00	10.77
31	0.29	0	30.00	0.00	100.00	293.00	9.77
32	0.29	0	30.00	0.00	100.00	263.00	8.77
33	0.29	1	29.50	3.33	96.67	233.00	7.77
34	0.28	2	28.00	6.90	93.10	203.50	7.02
35	0.26	1	26.50	3.70	96.30	175.50	6.50
36	0.25	0	26.00	0.00	100.00	149.00	5.73
37	0.25	3	24.50	11.54	88.46	123.00	4.73
38	0.23	2	22.00	8.70	91.30	98.50	4.28
39	0.21	6	18.00	28.57	71.43	76.50	3.64
40	0.15	3	13.50	20.00	80.00	58.50	3.90
41	0.12	0	12.00	0.00	100.00	45.00	3.75
42	0.12	1	11.50	8.33	91.67	33.00	2.75
43	0.11	2	10.00	18.18	81.82	21.50	1.95
44	0.09	5	6.50	55.56	44.44	11.50	1.28
45	0.04	1	3.50	25.00	75.00	5.00	1.25
46	0.03	3	1.50	100.00	0.00	1.50	0.50

x=developmental stage in days, l_x=proportion of number entering stage, d_x=number dying in stage x, L_x=number alive between age x and x+1, 100_{qx}=percent apparent mortality, S_x=survival rate within stage, T_x=Total number of age x units beyond the age, e_x=life expectancy

Table 4: Age-Specific Life Table of *P. marginatus* (Cohort 4)

X	l_x	d_x	L_x	100_{qx}	S_x	T_x	e_x
1	1.00	0	100.00	0.00	100.00	2318.00	23.18
2	1.00	0	100.00	0.00	100.00	2218.00	22.18
3	1.00	0	100.00	0.00	100.00	2118.00	21.18
4	1.00	0	100.00	0.00	100.00	2018.00	20.18
5	1.00	0	100.00	0.00	100.00	1918.00	19.18
6	1.00	0	100.00	0.00	100.00	1818.00	18.18
7	1.00	0	100.00	0.00	100.00	1718.00	17.18
8	1.00	4	98.00	4.00	96.00	1618.00	16.18
9	0.96	5	93.50	5.21	94.79	1520.00	15.83
10	0.91	8	87.00	8.79	91.21	1426.50	15.68
11	0.83	4	81.00	4.82	95.18	1339.50	16.14
12	0.79	2	78.00	2.53	97.47	1258.50	15.93
13	0.77	1	76.50	1.30	98.70	1180.50	15.33
14	0.76	1	75.50	1.32	98.68	1104.00	14.53
15	0.75	2	74.00	2.67	97.33	1028.50	13.71
16	0.73	3	71.50	4.11	95.89	954.50	13.08
17	0.70	3	68.50	4.29	95.71	883.00	12.61
18	0.67	1	66.50	1.49	98.51	814.50	12.16
19	0.66	0	66.00	0.00	100.00	748.00	11.33
20	0.66	1	65.50	1.52	98.48	682.00	10.33
21	0.65	5	62.50	7.69	92.31	616.50	9.48
22	0.60	10	55.00	16.67	83.33	554.00	9.23
23	0.50	14	43.00	28.00	72.00	499.00	9.98
24	0.36	5	33.50	13.89	86.11	456.00	12.67
25	0.31	1	30.50	3.23	96.77	422.50	13.63
26	0.30	0	30.00	0.00	100.00	392.00	13.07
27	0.30	0	30.00	0.00	100.00	362.00	12.07
28	0.30	0	30.00	0.00	100.00	332.00	11.07
29	0.30	0	30.00	0.00	100.00	302.00	10.07
30	0.30	0	30.00	0.00	100.00	272.00	9.07
31	0.30	1	29.50	3.33	96.67	242.00	8.07
32	0.29	0	29.00	0.00	100.00	212.50	7.33
33	0.29	2	28.00	6.90	93.10	183.50	6.33
34	0.27	1	26.50	3.70	96.30	155.50	5.76
35	0.26	3	24.50	11.54	88.46	129.00	4.96
36	0.23	1	22.50	4.35	95.65	104.50	4.54
37	0.22	6	19.00	27.27	72.73	82.00	3.73
38	0.16	2	15.00	12.50	87.50	63.00	3.94
39	0.14	3	12.50	21.43	78.57	48.00	3.43
40	0.11	1	10.50	9.09	90.91	35.50	3.23
41	0.10	1	9.50	10.00	90.00	25.00	2.50
42	0.09	5	6.50	55.56	44.44	15.50	1.72
43	0.04	1	3.50	25.00	75.00	9.00	2.25
44	0.03	0	3.00	0.00	100.00	5.50	1.83
45	0.03	2	2.00	66.67	33.33	2.50	0.83
46	0.01	1	0.50	100.0	0.00	0.50	0.50

x=developmental stage in days, l_x=proportion of number entering stage, d_x=number dying in stage x, L_x=number alive between age x and x+1, 100_{qx}=percent apparent mortality, S_x=survival rate within stage, T_x=Total number of age x units beyond the age, e_x=life expectancy

Overall, the high mortalities were recorded in nymphal stages especially in early instar stage, then gradually decreased in later instars. Survivorship curves (l_x) of *P. marginatus* studies on four cohorts are shown in figure 1 which falls in type III as classified by Pearl (1928) [13].

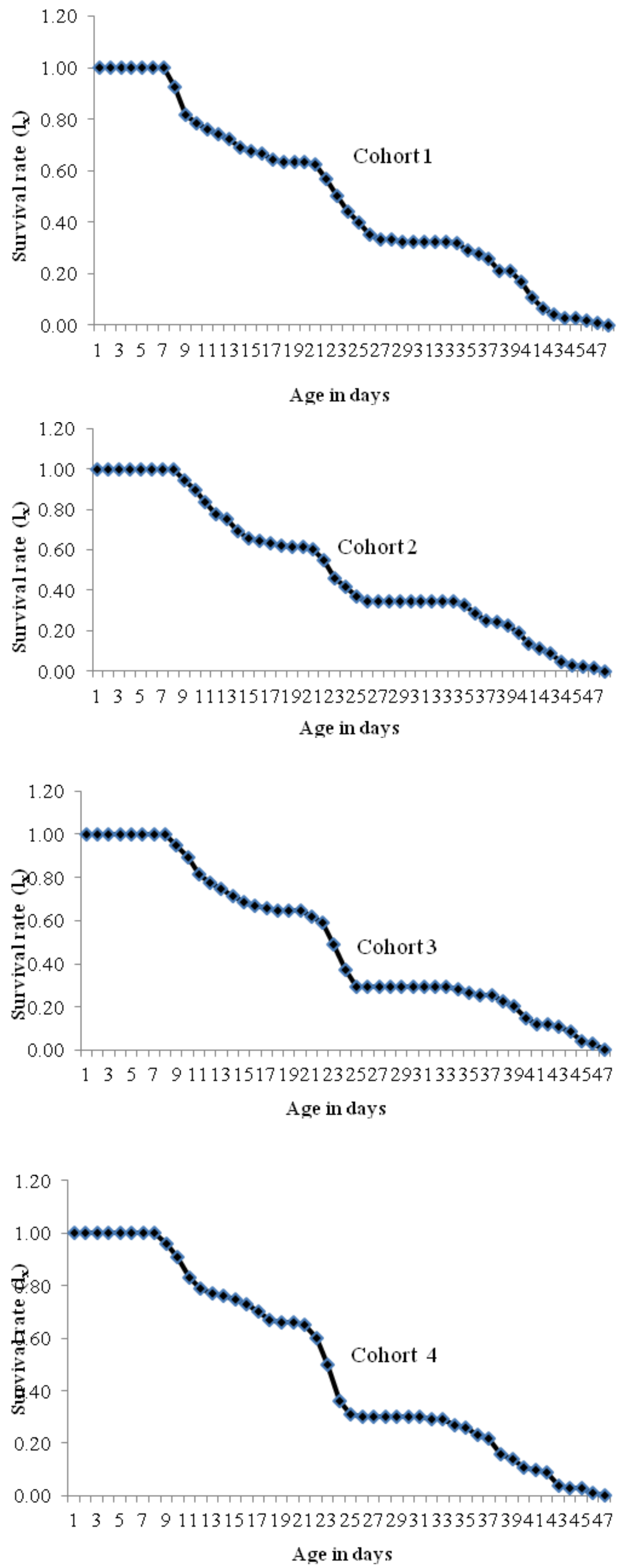

Figure 1: Patterns of Survivorship Curves (l_x) of four cohorts of *P. marginatus*

The little difference between survivorship curves of cohorts 1, 2 and 3, 4 was noticed. In cohorts 3 and 4, the survivalship curves abruptly fall down most probably due to higher number of males as compared to 1 and 2 cohorts. The female : male sex ratio in each cohort (1, 2, 3 and 4) was 1.17:1, 1.33:1, 0.88:1 and 0.94:1 respectively. The duration of adult longevity of male mealybugs is generaly shorter than females because of non-functional mouthparts [14]. The studies on the life history of *P. marginatus* by using different constant temperatures showed that the adult longevity of male *P. marginatus* was about seven times less than females [15].

Table 5 shows pooled life table of *P. marginatus* for four cohorts concerning the pathway of population change–mortality. It indicates that out of 459 eggs of *P. marginatus*, only 63.62% individuals successfully reached at the adult stage with average sex ratio of 1.09:1 (Female: Male). Three moultings in females and four moultings in males were recorded in all survival individuals. The highest mortality was recorded in first instar nymphs (20.1%) with k-value 0.097 followed by second instar nymphs (9.25%) with k-value 0.042 and third instar nymphs/Prepupa/Pupa (7.01%) with k-value 0.03. However, minimum mortality was recorded in eggs (5.66%) with k-value 0.025. Highiest mortality in first instar nymphs may be due to overcrowding along the basal part of midrib of leaf and can be considered as key factor in regulating population size. The high mortality in 1st instar nymphs was also reported in many insects especially in mirid bug, rice plant hopper and Asian citrus psyllid [8, 9, 16].

Table 5: Stage-Specific Pooled Life Table of *P. marginatus*

X	l_x	L_x	d_x	100_{qx}	S_x	T_x	e_x	k-value
Eggs	459	446	26	5.66	94.34	1620.3	3.53	0.02532
1st instar	433	389.5	87	20.1	79.91	1174.3	2.71	0.09741
2nd instar	346	330	32	9.25	90.75	784.8	2.27	0.04214
3rd instar(F), Prepupa(M) & Pupa(M)	314	303	22	7.01	92.99	454.8	1.45	0.03154
*Adults	292	151.8						

*Adult sex ratio (Female:Male) = 1.09:1

x=developmental stage in days, l_x=proportion of number entering stage, d_x=number dying in stage x, L_x=number alive between age x and x+1, 100_{qx}=percent apparent mortality, S_x=survival rate within stage, T_x=Total number of age x units beyond the age, e_x=life expectancy

Age-specific fecundity table: Age-specific survivorship (l_x) and fecundity (m_x) of *P. marginatus* are shown in figure 2 based on a comprehensive data in table 6. The first adult female emerged on day 20 and the earliest egg laying was recorded just after 5 days of female emergence and egg laying almost continued till the death. The last female died on day 47. The average number of eggs female^{-1} laid was 275.91±49.3 with maximum possible fecundity of 592. Adult female laid the maximum number of eggs in earlier days of oviposition while, less number of eggs were laid in later days of adult female life span. The highest number of eggs (74.9%) were laid during 27th to 33rd day of adult female life while only 24.1% eggs were laid in remaining days. Life span and number of eggs recored in *P. marginatus* was more as compare to pink hibiscus mealybug [17] which shows the longer adult female longevity, with higher number of eggs. It is generally assumed that short developmental time with higher number eggs on a host reflects the suitability of the host plant tested.

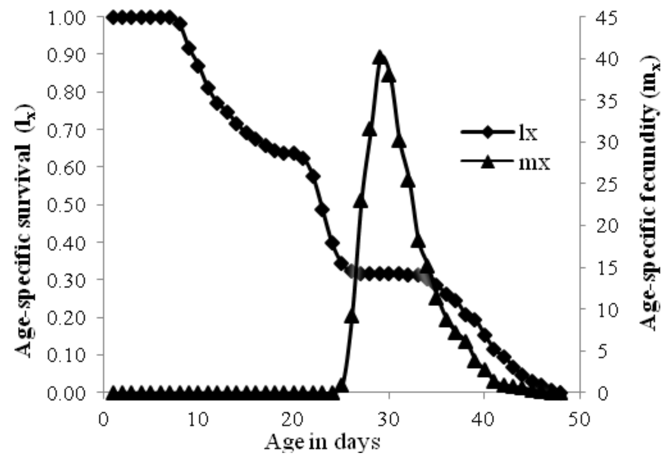

Figure 2: Age-Specific Survival (l_x) and Fecundity (m_x) of *P. marginatus*

Table 6: Age-Specific Life and Fecundity Table of *P. marginatus*

X	l_x	Eggs/ female	m_x	l_xm_x	xl_xm_x	$e^{-r_m x}(l_xm_x)$
1	1	0				
2	1	0				
3	1	0				
4	1	0				
5	1	0				
6	1	0				
7	1	0				
8	0.9813	0				
9	0.9173	0				
10	0.8708	0				
11	0.8104	0				
12	0.7700	0				
13	0.7480	0				
14	0.7152	0				
15	0.6921	0				
16	0.6764	0				
17	0.6584	0				
18	0.6427	0				
19	0.6384	0				
20	0.6384	0				
21	0.6246	0				
22	0.5756	0				
23	0.4875	0				
24	0.3976	0				
25	0.3441	0.9069	0.4730	0.1627	4.0685	0.0072
26	0.3218	9.1149	4.7537	1.5297	39.7726	0.0596
27	0.3176	23.0608	12.0269	3.8201	103.1428	0.1314
28	0.3176	31.5541	16.4564	5.2270	146.3571	0.1586
29	0.3155	40.1419	20.9352	6.6060	191.5749	0.1770
30	0.3155	38.0338	19.8358	6.2591	187.7731	0.1480
31	0.3155	30.1824	15.7411	4.9670	153.9780	0.1037
32	0.3130	25.5135	13.3061	4.1654	133.2933	0.0767
33	0.3130	18.1622	9.4721	2.9652	97.8520	0.0482
34	0.3035	15.2027	7.9287	2.4064	81.8192	0.0345
35	0.2862	11.3986	5.9447	1.7014	59.5506	0.0216

36	0.2611	8.7027	4.5387	1.1853	42.6693	0.0133
37	0.2454	7.1824	3.7459	0.9191	34.0051	0.0091
38	0.2087	6.1081	3.1856	0.6647	25.2604	0.0058
39	0.1951	3.8446	2.0051	0.3912	15.2582	0.0030
40	0.1534	2.6959	1.4060	0.2157	8.6260	0.0015
41	0.1162	1.3716	0.7153	0.0831	3.4071	0.0005
42	0.0960	0.9527	0.4969	0.0477	2.0023	0.0003
43	0.0693	0.7365	0.3841	0.0266	1.1442	0.0001
44	0.0468	0.6014	0.3136	0.0147	0.6452	0.0001
45	0.0309	0.3446	0.1797	0.0055	0.2495	0.0000
46	0.0195	0.0878	0.0458	0.0009	0.0411	0.0000
47	0.0057	0.0203	0.0106	0.0001	0.0028	0.0000
48	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Total	**275.92**	**143.90**	**43.36**	**1332.49**	**1.0000**

x=developmental stage in days, l_x=proportion of number entering stage, m_x=age-specific fertility that records the no. of living female offsprings born per female in each age interval, l_xm_x= l_x multiplied by m_x, xl_xm_x=developmental stage multiplied by l_xm_x

Table 7 describes the population and reproductive parameters of *P. marginatus*. The intrinsic rate of natural increase (r_m) of *P. marginatus* was 0.1248 per female per day and the daily finite rate of increase (λ) was 1.1329 female offsprings per female per day with mean generation time (T_c) of 30.73 days. The net reproductive rate (R_0) of population was 43.36 female offsprings per one female which indicates the rate of multiplication in one generation. Doubling time was recorded only 5.65 days. The intrinsic rate of natural increase was first applied by [12] as a measure of animal population growth rate and has since been used on many insects [18].

Table 7: Population and Reproductive Parameters of *P. marginatus*

No.	Parameters	Formula	Values
1	Approximate generation time (T_c) in days	$\sum (xl_xm_x) / \sum l_xm_x$	30.7327
2	Corrected generation time (T), in days	$\ln R_0 / r_m$	30.2007
3	Innate capacity for increase (r_c) day^{-1}	$\ln R_0 / T_c$	0.1227
4	Intrinsic rate of natural increase (r_m) day^{-1}	$\sum e^{-rmx} (l_xm_x)=1$	0.1248
5	Finite rate of increase (λ) in FOFD	e^{rm}	1.1329
6	Doubling time in days	$\ln 2 / r_c$	5.6500
7	Intrinsic birth rate (b)	$1 / \sum e^{-rmx} l_x$	0.167
8	Intrinsic death rate (d)	$b - r_m$	0.025
9	Gross reproduction rate	$\sum m_x$	143.90
10	Net reproduction rate (R_0) in FOF	$\sum l_xm_x$	43.36

Note: FOF: female offsprings $female^{-1}$; FOFD: female offsprings $female^{-1}$ day^{-1}

CONCLUSIONS

Based on finding of four cohorts it is concluded that the immature stage especially 1st instar of *P. marginstus* is more susceptible because remained mobile in search of suitable host tissue. The pest has stable population attributes with a large number of individuals (63.62%) reaching adult stages under suitable environmental conditions. The species shows high net reproductive rate (R_o) and finite rate of increase (λ) with lower generation (T) and doubling time which indicates rapid population buildup in short period of time.

ACKNOWLEDGEMENTS

This research is part of PhD study supported by Islamic Development Bank Scholarships Jeddah, Saudi Arabia and Research Grant by the Fundamental Research Grant Scheme (FRGS) from Ministry of Higher Education, Malaysia.

REFERENCES

[1] Deevey, E. S. Life tables for natural populations of animals. *The Quarterly Review of Biology*, **22**(4): 283-314 (1947).

[2] Rockwood, L. L. Introduction to population Ecology. Malden, M. A. Blackwell Publishing (2006).

[3] Bellows Jr, T., Van Driesche, R. and Elkinton, J. Life-table construction and analysis in the evaluation of natural enemies. *Annual Review of Entomology*, **37**(1): 587-612 (1992).

[4] Semea˜o, A. A., Martins, J. l. C. u., Picanc¸o, M. C., Bruckner, C. u. H., Bacci, L. and Rosado, J. F. Life tables for the guava psyllid *Triozoida limbata* in southeastern Brazil. *Biocontrol*, **57**(1) (2012).

[5] Southwood, T. R. E. Ecological methods with particular reference to the study of insect populations. 2nd Edition. Chapman and Hall. pp. 524 (1978).

[6] Aghdam, H. R., Fathipour, Y., Kontodimas, D. C., Radjabi, G. and Rezapanah, M. Age-specific life table parameters and survivorship of an Iranian population of the codling moth (Lepidoptera: Tortricidae) at different constant temperatures. *Annals of the Entomological Society of America*, **102**(2): 233-240 (2009).

[7] Payandeh, A. and Dehghan, A. Life table parameters of the dubas bug, *Ommatissus lybicus* (Hem: Tropiduchidae) at three constant temperatures. *African Journal of Biotechnology*, **10**(83): 19489-19493 (2011).

[8] Siswanto, M. R., Omar, D. and Karmawati, E. Life table and population parameters of *Helopeltis antonii* (Hemiptera: miridae) reared on cashew (*Anacardium occidentalel*). *Journal of Biosciences*, **19**(1): 91-101 (2008).

[9] Sule, H., Muhamad, R., Omar, D. and Hee, A. Life table and demographic parameters of Asian citrus psyllid *Diaphorina citri* on limau madu Citrus suhuiensis. *Journal of Entomology*, **9**(3): 146-154 (2012).

[10] Muniappan, R., B. M. Shepard, G. W. Watson, G. R. Carner, D. Sartiami, A. Rauf, and Hammig M. D. First Report of the Papaya Mealybug, *Paracoccus marginatus* (Hemiptera: Pseudococcidae), in Indonesia and India." *Journal of Agricultural and Urban Entomology* **25**(1): 37-40 (2008).

[11] Mastoi, M. I., Azura, A. N., Muhamad, R., Idris, A. B. and Ibrahim, Y. First report of papaya mealybug *Paracoccus marginatus* (Hemiptera: Pseudococcidae) from Malaysia. *Australian Journal of Basic and Applied Sciences*, **5**(7): 1247-1250 (2011).

[12] Birch, L. C. The intrinsic rate of natural increase of an insect population. *The Journal of Animal Ecology*, **17**(1): 15-26 (1948).

[13] Schowalter, T. D. Insect Ecology: An Ecosystem Approach (Third ed.): Elsevier. pp. 650 (2011).

[14] Williams, D. J. and Granara de Willink, M. C. Mealybugs of Central and South America. CAB International (1992).

[15] Amarasekare, K. G., Chong, J. H., Epsky, N. D. and Mannion, C. M. Effect of temperature on the life history of the mealybug *Paracoccus marginatus* (Hemiptera: Pseudococcidae). *Journal of Economic Entomology*, **101**(6): 1798-1804 (2008).

[16] Win, S. S., Ahmad, Z. A. M. and Adam, N. A. Life table and population parameters of *Nilaparvata lugens* Stal. (Homoptera: Delphacidae) on rice. *Tropical Life Sciences Research*, **22**(1): 27-39 (2011).

[17] Persad, A. and Khan, A. Comparison of life table parameters for *Maconellicoccus hirsutus*, *Anagyrus kamali*, *Cryptolaemus montrouzieri* and *Scymnus coccivora*. *BioControl*, **47**(2): 137-149 (2002).

[18] Lee, J. H., Lee, K. S. and Lee, H. P. Life table descriptions of *Tetrastichus* sp. (Hymenoptera: Eulophidae) on *Hyphatria cunea* Drury. *Korean Journal of Biological Sciences*, **6**(1): 19-22 (2002).